A Lateralized, Distributed Network for Semantic Processing Demonstrated with Whole Brain Functional MRI

J.R. Binder, S.M. Rao, T.A. Hammeke, J.A. Frost, R.W. Cox*, E.C. Wong*, P.A. Bandettini*, A. Jesmanowicz*, J.S. Hyde*

*Department of Neurology and *Biophysics Research Institute, Medical College of Wisconsin, Milwaukee, WI, USA*

Introduction

We previously reported left lateralized functional MRI (FMRI) signal changes during a single word semantic processing task, using a two-slice acquisition technique [1] which sampled only a portion of each hemisphere. We now describe FMRI responses measured during a similar linguistic task, using a whole brain imaging method.

Methods

Eight right-handed subjects were studied at 1.5 T. FMRI used a gradient-echo EPI sequence (TE 40ms, TR 6s, FOV 24cm, matrix 64x64, slice 7-8 mm). Sixteen sagittal images were obtained of the entire brain excluding the most lateral aspect of each temporal lobe. Auditory stimuli consisted of digitized tones and human speech, presented using a computer playback system. Sound was delivered by air conduction through plastic tubes inserted in the ears.

A semantic decision task was used to activate cognitive language functions. In this task, subjects heard nouns designating animals and were required to respond when the animal named was both "native to the United States" and "used by humans." A tone discrimination task was used as a control for auditory, motor, and attention functions. In this task, subjects heard groups of 3 to 7 sequential 500 or 750 Hz tones. A response was required for any tone sequence containing two occurrences of the 750 Hz tone. In each task, subjects responded with a single left finger button press. Stimuli for the two tasks were matched for duration, amplitude, rate, and target frequency.

Tasks were performed in a periodic manner, with 24s of one task alternating with 24s of the other task for 8 cycles. Pixels with incremental responses during the semantic task (i.e., "active") were identified by correlating data with ideal vectors on a pixel-by-pixel basis [2], with a significance threshold, after Bonferroni correction, of $p < .001$. "Active" pixels were superimposed on inverted FSE reference images acquired at the same locations as the echoplanar data, after interpolating the EPI data to a 256x256 matrix.

Results

All subjects had more active pixels in the left than in the right hemisphere ($p<.001$ in every subject). The main foci of activity were in the left lateral frontal lobe, left temporal-parietal-occipital junction, and left medial frontal lobe. Specific active structures on the left included the inferior frontal sulcus (Brodmann areas 9, 44-46), precentral sulcus (BA 6), angular gyrus (BA 39), posterior superior temporal sulcus and middle temporal gyrus (BA 21), posterior inferior temporal gyrus and collateral sulcus (BA 37), posterior medial aspect of the superior frontal gyrus (medial portion of BA 8, 9), and cingulate isthmus and subparietal sulcus (BA 23). Activity in the right hemisphere occurred in these same areas, but was less consistently present. Fig. 1 illustrates the location of active pixels in a typical subject.

The two most medial slices were frequently contaminated by high-amplitude signal artifacts, possibly due to gross brain motion at the interhemispheric fissure. We now use an arbitrary slice positioning procedure which lessens this problem by shifting the medial slices laterally a small distance, away from the medial surface.

Conclusions

By controlling for auditory sensory and general attention functions, the combination of tasks used in this study permitted identification of lateralized language systems participating in semantic processing. The multiple regions of activity suggest a distributed network with both frontal and posterior hemispheric components. The left frontal component has been observed previously under a variety of task conditions [3, 4], while the posterior component is in accord with studies showing severe loss of semantic information after injury to the left temporal and parietal regions [5], as occurs in fluent aphasia.

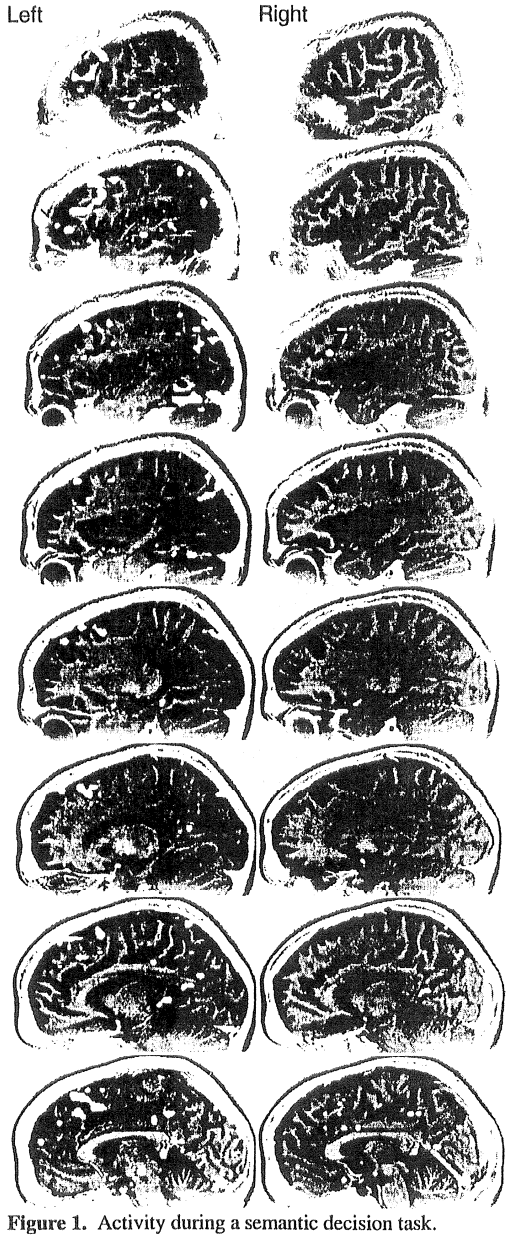

Figure 1. Activity during a semantic decision task.

References

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